All-Dielectric Hybrid Metasurface for Visible or Near-IR Applications

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Conventional all-dielectric metasurfaces made from high-index and low-loss materials (such as Si or GaAs) can achieve high optical efficiencies as well as broadband characteristics, mostly for the infrared (IR) light. However, maintaining the bandwidth and efficiency for conventional all-dielectric metasurfaces for visible or near-IR range becomes challenging, due to the limitations from material selection as well as fabrication techniques. To solve this problem, we proposed using hybrid all-dielectric metasurfaces to design better metasurfaces in shorter-wavelength range. The ultra-broadband reflector [1] and the full-color reflective display [2], as proof-of-principle demonstrations, are presented here.

Hybrid materials can solve the material limitation of all-dielectric metasurface (no high-index and low-loss materials) in visible and near-IR range. For example, in the ultra-broadband reflector based on hybrid metasurface (Figure 1a), high-index and high-loss material (amorphous Si) is used to define optical modes, while low-index and low-loss material (SiO_2 and Si_3N_4) are used to support the metasurface structure. Through engineering this four-layers hybrid metasurface structure, optical modes could have minimum overlap with a-Si layers, therefore only minimal loss is introduced. Broadband high reflectance in visible and near-IR range has been demonstrated. The bandwidth of >90% reflectance has been improved by to times to 150 nm (Figure 1e) from 15 nm (Figure 1d) of gratings without a-Si (Figure 1a).

Besides, hybrid metasurface can also be used to select desired optical resonances. For example, the performance full-color reflective display based on switchable all-dielectric metasurfaces (Figure 2a and 2b) is sensitive to the viewing angle, as shown in Figure 2c and 2g. As shown in Figure 2e, the desired optical resonance is mainly distributed at the center of nanopillars. If an amorphous Si cap is added to this switchable metasurface (Figure 2d), this new hybrid switchable metasurface design can decrease the unwanted side lobes in reflectance spectra obviously without reducing desired optical resonances (Figure 2f). This is because that the added a-Si cap is not at the location of desired optical resonances. Due to this, the viewing angle insensitivity of switchable metasurface can be increased hugely (Figure 2h).

Reference:
[1] Y. Yao, W. Wu, Adv. Opt. Mater. 2017, 5, 1700090;
[2] H. Liu, H. Yang, Y. Li, B. Song, Y. Wang, Z. Liu, L. Peng, H. Lim, J. Yoon, W. Wu, Adv. Opt. Mater. 2019, 1801639.

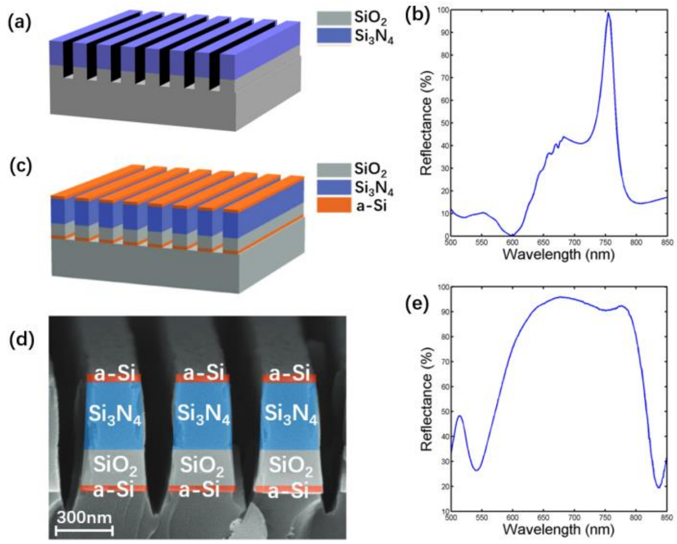

Figure 1: (a) Schematic of ultra-broadband reflector using conventional two-layers metausrfaces. (b) Simulated reflectance spectrum (TE-polarized) of the conventional hybrid metasurface. (c) Schematic of ultra-broadband reflector using four-layers hybrid metausrfaces. (d) Cross-sectional SEM image of the fabricated hybrid metasurface. (e) Measured reflectance spectrum (TE-polarized) of the fabricated hybrid metasurface.

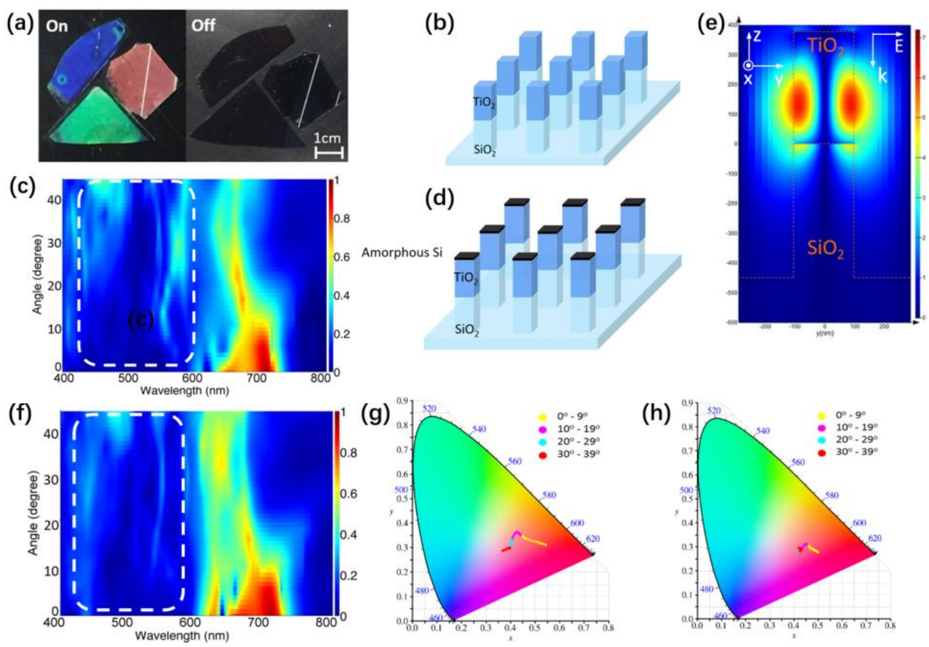

Figure 2: (a) Switchable all-dielectric metasurfaces can switch between “On” and “Off” state by introducing high-index liquid. (b) Schematic of switchable all-dielectric metasurfaces, which have two layers structure (TiO_2/ SiO_2). (c) Simulated reflection spectrum of the red metasurface versus the viewing angle. There are many side lobes in blue (400 - 500 nm) and green (500 - 600 nm) light range. (d) Schematic of hybrid all-dielectric design for red metasurface. (e) Simulated electric field distribution of the unit cell of red metasurface (Figure 2 (b)) at 710 nm normal incidence. (f) Simulated reflection spectrum of the hybrid red metasurface versus the viewing angle. The side lobes in blue and green light range decrease. (g) The color of red metasurface in CIE 1931 color map versus the viewing angle. (h) The color of hybrid red metasurface in CIE 1931 color map versus the viewing angle.